

Crashes with roadside objects along motorcycle lanes in Malaysia

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(Received 8 August 2007; final version received 25 October 2007)

Exclusive motorcycle lanes were introduced in Malaysia in the 1980s to reduce motorcyclist fatalities and they seem to be effective. However, no design guide has yet been developed for designing safer exclusive motorcycle lanes. The construction of Malaysian exclusive motorcycle lanes is based on the design criteria for cycle tracks [6], which does not suit the fast travelling and high volume of motorcycles along the exclusive lanes. According to the collected accident data, frequent motorcycle crashes still occur on exclusive motorcycle lanes. The present study found that roadside objects are one of the main contributing factors to motorcyclist fatalities. As a standard practice, guardrails have been planted along highways and roads. The design engineer of exclusive motorcycle lanes utilised the same practice and planted standard guardrails along exclusive motorcycle lanes. The suitability and the importance of the standard guardrail system as protection agent have been investigated and supported by real-world crash data. The catchment areas of the study were the top two longest exclusive motorcycle lanes in Malaysia: the exclusive motorcycle lanes along Federal Highway F0002 and the exclusive motorcycle lane along Shah Alam Expressway. Crash cases collected over 4½-year period were from the accident database of the authorities. A total number of 107 cases were recorded as motorcycle crashes involving roadside objects. Guardrails have been identified as the most struck object, representing 32.7% of all roadside object-related motorcycle crashes along exclusive motorcycle lanes. An odds ratio analysis has found that narrow surface objects contribute to higher fatality rate than guardrails. However, guardrails still contribute 23.5% of all fatal roadside object-related crashes and were found to be 1.7 times more likely to cause serious injury to motorcyclists than non-object-related motorcycle crashes. These findings support that guardrails are suitable to be used as a protection agent for the motorcyclists using the exclusive motorcycle lanes. However, further research and enhancements on the guardrail design system and material type are needed to have safer exclusive motorcycle lanes.

Keywords: motorcycle crash; motorcycle lane; road sided object; odd ratio analysis; motorcycle-guardrail crash

Introduction

Malaysia, as well as other countries which possess high volumes of motorcycles, is facing high motorcyclist fatalities. In Malaysia, many measures have been taken to reduce the number of these fatalities on the road every year. One of the most effective measures is the introduction of the exclusive motorcycle lane for motorcyclists. Exclusive motorcycle lanes were introduced to Malaysia in the 1980s. The exclusive motorcycle lane segregates the heavy motorcycle traffic from the main traffic stream. The segregation reduces the high number of motorcycle crashes involving other vehicles. A short-term reduction of 39% of motorcycle crashes was found after the introduction of the exclusive motorcycle lane along the Federal Highway F0002 in Malaysia [12].

However, motorcycle fatalities are still occurring along exclusive motorcycle lanes. These fatalities are due to mul-

tipile motorcycle crashes, single motorcycle crashes, and even due to motorcycles colliding into objects at the roadside. The occurrence of these motorcycle crashes may be due to the motorcycle lane's inappropriate geometric designs, inappropriate roadside designs, and even due to the lack of research on remedies carried out. At present, no proper design guide exists in the world, which can be referred to for designing an exclusive motorcycle lane. In Malaysia, Technical Directive *Arahan Teknik (Jalan) 10/86: A Guide to the Design of Cycle Track* is the only design guide available. However, this guide is still unsuitable to be used to design an exclusive motorcycle lane. The design parameters provided in this guide were determined using combinations of highway and cycle track design guides [6]. In addition, *Arahan Teknik Jalan 10/86* was developed and published in 1986; no revision has been made ever since, even though motorcycle traffic volume has increased

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tremendously since then. Clear zones are a feature of modern highways that have great impact on roadside safety [13]. The Technical Directive does not cover any roadside design parameters or guide. If only comprises a preferable design guide for exclusive motorcycle lanes, which is based on cycle track. Thus, it is important to know how to allocate proper clear zones and proper roadside objects so as to reduce motorcycle collisions with these roadside objects planted along the exclusive motorcycle lanes.

As a standard practice, guardrails have been planted along highways and major trunk roads to shield vehicles from hazards found along the roadside. The design engineer of exclusive motorcycle lanes has followed the same practice and planted standard guardrail systems along exclusive motorcycle lanes as well. The suitability of these guardrails planted along the exclusive motorcycle lanes is still in question. These guardrails are the potential contributors to motorcyclist fatality in crashes.

From the issues stated earlier, the importance of this study to be carried out is recognised. This study has been carried out to contribute knowledge with the aim of producing better roadside designs for exclusive motorcycle lanes. The suitability and the importance of the standard guardrail system as a protection agent have been investigated and supported by real-world crash data. The present study also investigates roadside objects as one of the main contributing factors of motorcyclist fatalities along the lanes. This study provides a clearer view of the relationship between the type of objects planted and the injury severity of motorcycle crashes that occur along the existing exclusive motorcycle lanes.

Methodology

Catchment area

The catchment areas of the study were identified and investigations were carried out at the top two longest exclusive motorcycle lanes in Malaysia, namely, the exclusive motorcycle lanes along Federal Highway F0002 (Figure 1) and the exclusive motorcycle lane along Shah Alam Expressway (Figure 2). The reasons that these two lanes were selected for this study are as follows: both lanes are the two longest exclusive motorcycle lanes in Malaysia, are the oldest constructed exclusive motorcycle lanes in Malaysia and carry the highest motorcycle volume in the Klang Valley, Malaysia.

Data set

In this study, motorcycle crashes that occurred along both selected exclusive motorcycle lanes were targeted. Only cases involving fatal and other non-fatal injuries, which occurred along the lanes, were collected. The non-injury cases were found to be under-reported. Therefore, these cases were excluded from the study. The data set comprised cases that occurred during four and a half years between 1998 and 2003. All the cases were collected from traffic police (for cases that occurred along Federal Highway F0002) and highway authority (for cases that occurred along Shah Alam Expressway).

The casualties' details collected from the traffic police and highway authority were used as the initial records for search for injury details in hospitals. The injury records from the hospitals were being used as verification of the injury severities of the crashes. Table 1 shows the details



Figure 1. Exclusive Motorcycle Lane along Federal Highway F0002.

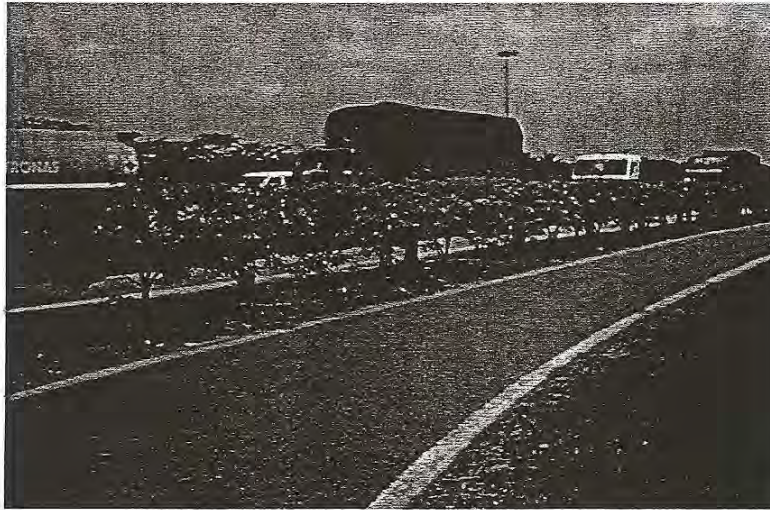


Figure 2. Exclusive Motorcycle Lane along Shah Alam Expressway.

collected from the traffic police, highway authority and hospitals.

Injury classification

Injuries of each casualty were categorised into fatal injury, serious injury and minor injury. Fatal cases were cases in which death occurred within 30 days or less as a result of the crash [2,14,16]. Serious injury cases were cases in which motorcyclists were admitted into the hospitals as in-patients for any of the following injuries: fractures, concussion, internal injuries, crushing, severe cuts and lacerations, or se-

vere general shock requiring medical treatment [2]. Minor injury cases referred to injuries such as sprains, bruises or cuts or lacerations not judged to be severe, slight shock, and those which required only roadside attention [2,14].

In analysing roadside-object-related cases, the levels of injury severity were finalised and categorised as severe injury and minor injury. Severe injury cases included fatal and serious injury cases. Fatal cases and serious injury cases were combined to avoid statistical inadequacy due to the low number of reported fatal roadside-object-related cases, which involved roadside objects, throughout the study period.

Table 1. The collected details from the respective sources.

Location/source	Information collected
Traffic Police and Highway Authority	<ol style="list-style-type: none"> 1. Type of motorcycle crashes <ul style="list-style-type: none"> • Single vehicle crash • Multiple vehicle crash 2. Motorcycle crash patterns 3. Motorcycle crash locations 4. Type of roadside furniture involved in the motorcycle crashes 5. Early description of the site locations 6. The hospital to which the casualties were admitted 7. Casualties' personal information
Hospitals	<ol style="list-style-type: none"> 1. Casualties' personal information 2. Injury severity of the motorcyclists involved <ul style="list-style-type: none"> • Fatal • Serious injury • Minor injury

Data analysis

The collected cases were then filtered accordingly for further analysis. All motorcycle crashes involving roadside objects were filtered out from the data set for roadside-object-related motorcycle crashes analysis. Odds ratio and chi-square (χ^2) analyses were carried out to determine the relationship between variables. Chi-square tests were done to determine the independencies between the two variables. As an aid in interpreting the level of dependency between the tested variables, data were presented as odds ratios. An odds ratio represents the rate of involvement as a relative quotient. The odds ratios for the independent variable were determined from the contingency tables.

Results and discussion

Motorcycle crashes along exclusive motorcycle lane

A total number of 620 motorcycle accident cases were collected from both the police and the highway authority

throughout the study period. These crashes suited the criteria made, which were motorcycle crashes that occurred along exclusive motorcycle lanes and that these motorcycle crashes involved injuries. Non-injury cases were omitted because these cases were found to be under-reported. The majority of the non-injury cases were not reported to the authorities. Out of the total reported motorcycle crashes, 8.0% were reported as fatal cases, 40.0% as seriously injured cases, and 52.0% as only involving minor injuries. The present distribution of injury pattern shows a similarity to a study on 450 motorcycle crashes that occurred along mixed traffic roads by Whitaker (1980), which showed 54% of the crashes were minor injury cases, 44% had moderate or severe injury while 1% were reported as fatal cases [16]. The pavement, crashed motorcycles and the roadside object hit were found to be the agents which caused injuries to the motorcyclists. A total of 47.4% of the cases referred to the motorcyclist losing control, falling on the pavement, and being injured as a result. In another 17.2% of the cases, motorcyclists were injured when they lost control, followed by a collision with roadside objects. The rest (35.3%) were injured due to collisions with other motorcycles while travelling on the exclusive motorcycle lanes.

Motorcycle crashes involving roadside object

From the total number of 620 collected cases, 17.3% were related to collisions with roadside objects. A total of 15.9% of these cases were reported as fatal motorcycle crashes, while the other 84.1% were classified as non-fatal motorcycle crashes. The fatalities related to collisions with roadside objects constituted 34% of the total fatalities along exclusive motorcycle lanes. Table 2 shows the comparison of injury severity distribution for roadside-object-related and non-roadside-object-related motorcycle crashes.

The odds ratio analysis shows that a roadside-object-related motorcycle crash was 2.0 times more likely to be a fatal crash than a non-roadside-object-related motorcycle crash along the exclusive motorcycle lanes (Table 3). Numerous studies have been carried out on motorcycle crashes along mixed traffic roads and showed similarities to the findings of this study, which is that the involvement of roadside

Table 3. The comparison of roadside-object-related and non-roadside-object-related motorcycle crashes.

Injury severity	Roadside object involvement in motorcycle crashes		Total
	Roadside object related	Non-roadside object related	
Fatal	13	34	47
Non-fatal	94	479	573
Total	107	513	620

Note. $\chi^2 = 3.853$, $df = 1$, $p < 0.10$.

objects produced higher levels of injury severity compared to no-object-involvement crashes [1,7,8,10,11,15]. This is because during the crash that does not involve any object the impact created tends to be less or non-energy-absorbing [8]. Upon collision with the objects, the motorcycle and the motorcyclist absorb most of the impact energy which can have caused greater injury severity.

The objects involved in motorcycle crashes

The data revealed that guardrails have the highest frequency of involvement (32.7%), followed by tunnel walls (29.9%), drainage and kerbs (12.1%), trees (5.6%), street lighting posts (5.6%), traffic sign poles (3.7%), concrete walls (3.7%), other types of barriers (1.9%), fences' posts (0.9%), concrete columns (0.9%), bridges' rails (0.9%) and non-fixed objects (1.9%).

The types of roadside object involved in motorcycle crashes were divided into narrow surface objects and non-narrow surface objects. Narrow surface objects are objects which contribute as points of impact during a crash. Some examples are street-lighting columns, traffic sign poles, trees and guardrails' end treatment. Non-narrow surface objects were divided into wide surface objects, drainage and kerbs, and non fixed objects. A wide surface object has a broader contact surface during a crash than a narrow surface object. Guardrails and tunnel walls were included as roadside objects in this category. The data unveiled that the fatality involving narrow surface objects represented 58.0% of all fatal crashes involving roadside objects. Table 4 shows the distribution of injury severity caused while crashing into different categories of objects along the exclusive motorcycle lanes. Odds ratio analysis showed that a narrow surface object is 3.0 times more likely to cause severe injury rather than minor injury as compared with non-narrow surface object in roadside motorcycle crashes along exclusive motorcycle lanes ($p < 0.10$). Narrow surface objects tend to cause severe injury in roadside-object-related motorcycle crashes along the exclusive motorcycle lanes. The injury severity in roadside-object-related motorcycle crashes is related to the impact area and the rigidity of the object.

Table 2. The distribution of injury severity for roadside-object-related and non-roadside-object-related motorcycle crashes along exclusive motorcycle lanes.

Injury severity roadside	Object related motorcycle crashes	Non-roadside object related motorcycle crashes
Fatal	17 (15.9%)	34 (6.6%)
Serious injury	37 (34.6%)	205 (40.0%)
Minor injury	53 (49.5%)	274 (53.4%)
Total	107 (100%)	513 (100%)

Table 4. Types of object involved and injury outcome.

Injury severity	Object type		Total	Odds ratio
	Narrow surface object	Non-narrow surface object		
Severe injury	17	37	54	3.0
Minor injury	7	46	53	
Total	24	83	107	

Note. $\chi^2 = 4.69$, $df = 1$, $p < 0.10$.

[11]. The impact forces are not localised and not severe when motorcycles collide into large surface impact areas (such as tunnel walls and roadside barriers) and at small impact angles [9]. Therefore, the existing roadside furniture along the exclusive motorcycle lanes might not have been appropriately designed to suit motorcycles/motorcyclists.

Motorcycle crashes involving guardrails

During the study period, 30 motorcycle crashes were reported, which involved guardrails. Out of the total number of these crashes, 13.3% were reported as fatal. The fatality involving guardrails represented 23.5% of all fatal crashes involving roadside objects. This shows that the guardrails contributed to motorcyclists' fatalities along the exclusive motorcycle lanes. This questioned the suitability of the existing guardrail design along the lanes.

An additional odds ratio analysis (Table 5) was carried out and it was found that guardrails are 1.7 times more likely to cause severe injury than non-object-related motorcycle crashes along the lanes. This result shows that the construction of the existing guardrails along the exclusive motorcycle lanes did not consider the risk of injury during a motorcycle crash involving guardrails. Studies have been carried out to investigate the suitability of the existing guardrails to motorcyclists [4,5]. However, these researches have so far been unable to determine the best-suited guardrail design for motorcyclists, especially along the exclusive motorcycle lanes. Therefore, more studies and crash tests need to be

Table 5. The comparison of guardrails and non-object-related motorcycle crashes along exclusive motorcycle lanes.

Injury severity	Guardrails/no objects		Total	Odds ratio
	Guardrail related motorcycle crashes	Non-object related motorcycle crashes		
Severe injury	18	239	257	1.7
Minor injury	12	274	286	
Total	30	513	543	

Note. $\chi^2 = 2.60$, $df = 1$, $p < 0.10$.

Table 6. Comparison between narrow surface objects and guardrails.

Injury severity	Object type		Total	Odds ratio
	Narrow surface object	Guardrail		
Severe injury	17	18	34	1.6
Minor injury	7	12	20	
Total	24	30	54	

Note. $\chi^2 = 4.26$, $df = 1$, $p < 0.10$.

carried out in order to prepare a more motorcyclist-friendly guardrail design system.

Guardrail vs. narrow surface object

In another comparison involving guardrails, the odds ratio analysis showed that in a crash, a narrow surface object was 1.6 times more likely to cause severe injury than a guardrail ($p < 0.10$) (Table 6). In the crashes, a guardrail seemed to perform as a better kinetic impact energy absorber than the narrow surface object.

The injury severity outcome in the crashes was lower compared to the narrow surface object. Guardrails are planted at the roadside parallel to the travelling path. After the collision with a guardrail, the motorcycle is likely to slide along the surface of the guardrail. Therefore, the collision impact is less compared to striking the narrow surface object while travelling along the path. This finding seems similar to the findings of a few researchers done on motorcycle crashes into objects in Australia, Los Angeles and Canada. Their research showed that narrow surface objects tended to cause more severe injuries to the motorcyclist than guardrails [1,3,11]. These findings show that the guardrail still performs as a protection agent against narrow objects along the exclusive motorcycle lanes.

Conclusion

Narrow surface objects contributed to a higher fatality rate than guardrails. Narrow surface objects represented 58.8% of all fatal crashes along the lanes. Odds ratio analysis has shown that a narrow surface object is 1.6 times more likely to cause severe injury than a guardrail. These findings show that a guardrail is suitable to be used as the protection agent for the motorcyclists along the exclusive motorcycle lanes. Nevertheless, guardrails still contribute 23.5% to all fatal roadside-object-related crashes along the lanes. This is consistent with the general perception that the existing design of the guardrail system is not suitable for exclusive motorcycle lanes. The stiffness and the rigidity of the existing guardrail do influence the injury severity in motorcycle crash. A different and better type and design of guardrail system is therefore needed for

safer exclusive motorcycle lanes. Limited injury data from hospitals, huge numbers of under-reported cases, and the absence of a proper mechanism for getting speed data have constrained the content of the present study. Further analyses with the support of the above data and information may provide a more comprehensive understanding of roadside-object-related crashes along exclusive motorcycle lanes.

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